Southern California Priority Corridor
Showcase Program Evaluation

System Performance Cross-Cutting Evaluation Report

FINAL

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Disclaimer

Abbreviations & Acronyms

ATIS	Advanced Traveler Information System
ATMIS	Advanced Traffic Management & Information System
ATMS	Advanced Transportation Management System
AVL	Automatic Vehicle Location
Caltrans	California Department of Transportation
CCTV	Closed-circuit Television surveillance camera
CEO	Chief Executive Officer
CFO	Chief Financial Officer
CHP	California Highway Patrol
CM	Configuration Management
CMP	Configuration Management Plan
CMS	Changeable Message Sign
CORBA	Common Object Request Broker Architecture
COTS	Commercial Off-the-Shelf
CTC	California Transportation Commission
CVO	Commercial Vehicle Operations
CW	Corridor-wide
CWATIS	Corridor-wide Advanced Traveler Information System Project
CWATMS	Corridor-wide Advanced Transportation Management System Project
CWCVO	Corridor-wide Commercial Vehicle Operations Project
CWSIP	Corridor-wide Systems Integration Project
CWSPP	Corridor-wide Strategic Planning Project
DOIT	Department of Information Technology
DRI	Caltrans Division of Research & Innovation (formerly NTR)
EAP	Evaluation Activity Plan
EP	Evaluation Plan
FHWA	Federal Highway Administration
FSR	Feasibility Study Report
FTA	Federal Transit Administration
FTE	Full-Time Equivalent (one full-time employee)
GPRA	Government Performance and Results Act
GUI	Graphical User Interface
HP	Hewlett-Packard
HQIT	Headquarters - Information Technology (division of Caltrans)
IDL	Interface Definition Language
IPP	Implementation Phasing Plan
IPR	Intellectual Property Rights
ISP	Information Service Provider
ISSC	Information Systems Service Center (division of Caltrans)
ISTEA	Intermodal Surface Transportation Efficiency Act (of 1991)
ITS	Intelligent Transportation Systems
LACDPW	Los Angeles County Department of Public Works
LADOT	City of Los Angeles Department of Transportation

LAN	Local Area Network
MOU	Memorandum of Understanding
MPO	Metropolitan Planning Organization
MTA	Los Angeles County Metropolitan Transportation Authority
MTBF	Mean Time Between Failure
NDA	Non-Disclosure Agreement
NET	National Engineering Technology Corporation
NTCIP	National Transportation Communications for ITS Protocol
NTR	Caltrans Division of New Technology & Research (now DRI)
OCMDI	Orange County Model Deployment Initiative
OCTA	Orange County Transportation Authority
O&M	Operations and Maintenance
OS	Operating system (such as Windows™, Unix, Linux, et. al.)
PC	Personal Computer (Windows™-based)
PoP	Period of Performance
RAMS	Regional Arterial Management System (aka. Traffic Signal Integration)
RAVL	Regional AVL (aka. Transit Management System)
RCTC	Riverside County Transportation Commission
RFP	Request for Proposals
RTP	Regional Transportation Plan
RTPA	Regional Transportation Planning Agency
RWS	Remote Workstation
SANBAG	San Bernardino Association of Governments
SANDAG	San Diego Association of Governments
SCAG	Southern California Association of Governments
SCAQMD	South Coast Air Quality Management District
SCPCSC	Southern California Priority Corridor Steering Committee
TEA-21	Transportation Equity Act for the 21st Century
TIC	Traveler Information Center
TMC	Transportation Management Center
TOC	Traffic/Transportation Operations Center
USDOT	United States Department of Transportation
VCTC	Ventura County Transportation Commission
VDS	Vehicle Detector Station
VMT	Vehicle Miles Traveled
VOS	Volume/Occupancy/Speed
WAN	Wide Area Network

Executive Summary

This cross-cutting report aggregates and summarizes the cumulative knowledge gained from the several Showcase Program projects with regards to system development and performance. The report looks at their combined experiences and synergistic impacts, as opposed to the experiences and impacts of any one system in isolation. Each Showcase cross-cutting report addresses one of the Showcase Program's five evaluation goals:

- ✓ System Performance
- ✓ Costs
- ✓ Institutional Impacts
- ✓ Transportation and Traveler Information Management
- ✓ Transportation System Impacts

Background

As required by federal law, all Intelligent Transportation System (ITS) projects that receive federal funding must undergo an evaluation to help assess the costs and benefits of ITS. This document is one of 23 reports produced as part of the Southern California ITS Priority Corridor Showcase Program Evaluation to help planners and decision-makers at the federal, state and local levels make better-informed decisions regarding future ITS deployments.

In 1993, the U.S. Department of Transportation designated Southern California as one of four Priority Corridors in which Intelligent Transportation System (ITS) could have particular benefit. Southern California suffers from extreme traffic congestion, limited room for expanding transportation facilities, and above-average air pollution levels. The Southern California Priority Corridor is one of the most populated, traveled, and visited regions in the country, and consists of four adjoining regions:

- Los Angeles/Ventura
- Orange County
- San Diego County
- Inland Empire (San Bernardino and Riverside Counties).

The ITS Showcase Program is one of several programs that have been implemented in Southern California's Priority Corridor to help aid mobility and mitigate traffic congestion and its associated environmental impacts. The Showcase Program consists of 17 ITS projects that collectively form a corridor-wide intermodal transportation management and information network between Los Angeles, Orange County, San Diego, and the Inland Empire. Each Showcase project deploys a piece of this Corridor-wide ITS network, including regional Advanced Traveler Information Systems (ATIS), regional Advanced Transportation Management Systems (ATMS), and regional and interregional communications infrastructure. Eleven of the projects are regional in nature, while the remaining six are Corridor-wide. The projects are listed in the table below.

PROJECT	DESCRIPTION
Corridor-wide Projects (6)	
Scoping & Design (Showcase Kernel)	Designs and implements four "Kernel" servers that help manage the interregional Showcase Network. One Showcase Kernel will be installed in each of the four Southern California Caltrans Districts.
Strategic Planning/System Integration (CWSPP)	Works to ensure that the systems of the Priority Corridor are interoperable and sustainable by developing a Configuration Management process.
CWATIS	Will provide Concept of Operations (ConOps), System Requirements and High Level Design for an Integrated Workstation (IWS).
CWATMS	Intended to build on the high-level planning efforts of the CWATIS project and develop the IWS.
Interregional Rideshare Database	Links San Diego's transit database with the transit database at Southern California Association of Governments (SCAG) in order to make SCAG's transit based Itinerary Planning tool more robust. The change will broaden the system's coverage from the LA/Orange County area to include San Diego as well.
CWCVO	Primarily intended for Commercial Vehicle Operations (CVO), the Showcase portion of CWCVO develops a server that fuses transportation data and provides an interface for partner Information Service Providers (ISPs) to access it for value-added redistribution.
San Diego Regional Projects (5)	
IMTMS/C	Optimizes and coordinates freeway and surface street operations with public and private transportation systems by integration of intermodal transportation information, and intermodal transportation management systems. Creates an ITS network for the San Diego region.
InterCAD	Improves incident management by linking the Computer-Aided Dispatch (CAD) systems of law enforcement and emergency response agencies in San Diego.
Mission Valley ATMIS	Optimizes traffic and transit operations in the vicinity of Qualcomm Stadium. The project coordinates with the IMTMC/S project.
Transit Management System (RAVL)	Installs Automatic Vehicle Locator (AVL) on San Diego Transit buses, as well as provides traffic signal priority at a number of downtown intersections.
Traffic Signal Integration (RAMS)	Integrates remote management of traffic signals across multiple jurisdictions in San Diego County.
Los Angeles/Ventura Regional Projects (3)	
IMAJINE	Creates an integrated network comprising four transportation management systems in Los Angeles County: Caltrans District 7 freeway management system, Los Angeles County Metropolitan Transit Authority (LACMTA) fixed route transit database, Access Services Inc. (ASI) demand-based paratransit services, and the City of South Gate arterial traffic signal control system.
Integrated Mode Shift	Provides transit-related traveler information in the form of trip itineraries. Also provides driving directions for automobile trips.
LA/Ventura ATIS	Implements an ATIS for LA County and some Ventura County commuters. In the future, the system may also bundle public data from various sources and make it available to ISPs.

Orange County Regional Projects (2)	
TravelTIP	Fuses data from multiple jurisdictions throughout Orange County and disseminates it to travelers via a website, a Highway Advisory Telephone (HAT) system, and three kiosks.
OCMDI	Extends the dissemination of traveler information in Orange County by providing data to private sector ISPs through a non-profit data broker. The data broker is called the Traveler Advisory News Network (TANN). TANN's goal is to be the single interface for traveler information in California. TANN establishes connections with public and private data sources, and then acts as a broker to provide data and/or information services to ISPs and other media outlets.
Inland Empire Regional Projects (1)	
Fontana-Ontario ATMIS	Built a Traffic Management Center (TMC) for the City of Fontana and a regional ATIS to help manage traffic from sources such as the Ontario Convention Center, Ontario Mills Mall, Ontario International Airport and the California Speedway in Fontana. Additionally, the project integrates the new TMC with the Showcase Network via the Inland Empire Kernel located at Caltrans District 8.

The Showcase Evaluation studied each of these 17 projects, and a project evaluation report has been prepared for each one.

This cross-cutting report summarizes the cumulative knowledge gained over all of the projects with regards to system development and performance.

Evaluation Findings, Conclusions, and Recommendations

The probability of success of an ITS project is often determined before its contract is signed. When contracting ITS projects, agencies should consider several issues:

- Have Intellectual Property Rights (IPR) regarding the source code of any custom-developed software been adequately addressed in the Request for Proposals (RFP) and the contract template?
- If other systems might eventually integrate with this one, will its interfaces be properly documented "as built?"
- Are the expectations for the project realistic?
- Is the project compliant with the National ITS Architecture?

In general, legal precedents restrict public agencies from sharing custom-developed software source code with private third-parties, even if the software development was entirely funded by the public sector. This is because the source code may contain proprietary innovations or "trade secrets" of the developer, which may not be disclosed to the marketplace. However, agencies that have their own Information Technology staff may often negotiate the right to view and modify the code “in house” or to share the source code with other public agencies within the same region or state. Such sharing can benefit regional standardization and integration.

Projects – particularly those that develop infrastructure – should not underestimate the importance of completely and accurately documenting system designs and interfaces. Many projects finalize their design documents at the end of the Design task, but before the implementation is complete. However, design changes often continue to take place as the developer encounters and overcomes the inevitable and unforeseen technical challenges that arise. To ensure that all of these changes are recorded, projects should budget for ongoing revision of design documentation until the end of the project, resulting in “as built” documentation.

Most of the Showcase projects required more than 48 months to complete even though their original schedules were for 18-24 months. As opposed to calling the projects “late,” it seems more realistic that the level of effort was underestimated and that the original schedules were simply too aggressive. The Showcase Program revealed that – due to the vast amounts of interagency coordination often required – the Requirements and High-Level Design phases of an integration project can take 18-36 months alone, only to be followed by another 18-24 months of detailed design, implementation, installation, and testing. In the near term, ITS projects throughout the country should be expected to continue this pattern, though successive regional deployments and the development of regional architectures should eventually help streamline the process.

In early 2001 – roughly six years after the start of the Showcase Program – the Federal Highway Administration issued its “Rule on Intelligent Transportation Systems and Standards.” The Rule contains two particularly important high-level requirements (and several supporting detailed requirements) regarding ITS planning and project implementation:

1. “A regional ITS architecture shall be developed to guide the development of ITS projects and programs and be consistent with ITS strategies and projects contained in applicable transportation plans.”

2. “All ITS projects funded with Highway Trust Funds shall be based on a systems engineering analysis that is on a scale commensurate with the project scope.”

One of the detailed supporting requirements in the Rule refers to developing an “operational concept” to define the roles and responsibilities of the participating agencies and to plan ahead for operations and maintenance. In practice, this can be achieved through the development of a Concept of Operations (ConOps) document.

A ConOps is a useful first step in a project because it can help the project stakeholders establish a common vision of the end product and a common understanding of how the system will be used. In addition, a ConOps can help uncover critical institutional issues early, such as:

1. Does the system require any shared use of field devices between agencies?

2. Does the system require access to any secure networks, as might belong to law enforcement/public safety?

3. Will the system require a human operator, or can it be automated? Are there any potential system operators available?

4. Are any interagency agreements or MOUs necessary to cover liability concerns or O&M costs?

The Showcase Program provides empirical evidence as to why a ConOps and the other requirements in FHWA's Rule are so important. The Showcase projects followed a logical systems engineering approach, but most of the projects began before the FHWA Rule was published and did not prepare a ConOps. As a result, several were impacted by institutional issues. Although the Showcase projects dealt with these issues eventually, identifying and resolving such issues early will help reduce risk and maximize a system's return on investment.

1 Introduction

1.1 Purpose and Scope of this Report

As required by federal law, all ITS programs that receive federal funding must undergo an evaluation to help assess the costs and benefits of ITS. For the Showcase Program, this includes:

- 17 individual project evaluation reports that each address:
  - ✓ System Performance
  - ✓ Costs
  - ✓ Institutional Impacts
  - ✓ Transportation and Traveler Information Management
  - ✓ Transportation System Impacts

- 5 cross-cutting evaluation reports that aggregate data and lessons learned from across the individual projects for each of the five topic areas listed above.

- 1 Summary Evaluation Report to summarize the cumulative knowledge and lessons learned from the Showcase Program.

The complete collection of reports produced by the Showcase Evaluation is listed below.

Document Type/Title	Date	Document Number
17 Individual Project Evaluation Reports		
Corridor-wide ATIS Project Report	7/16/2003	65A0030/0033
Corridor-wide ATMS Project Report	10/28/2004	65A0030/0049
Corridor-wide CVO Project Report	10/29/2004	65A0030/0051
Corridor-wide Rideshare Project Report	11/1/2004	65A0030/0048
Corridor-wide Strategic Planning Project Report	10/29/2002	65A0030/0028
Fontana-Ontario ATMIS Project Report	11/30/2004	65A0030/0047
IMAJINE Project Report	3/17/2003	65A0030/0029
IMTMC Project Report	11/24/2004	65A0030/0054
InterCAD Project Report	4/2/2003	65A0030/0030
Kernel Project Report	5/30/2003	65A0030/0031
LA ATIS Project Report	3/15/2004	65A0030/0038
Mission Valley ATMIS Project Report	11/12/2004	65A0030/0050
Mode Shift Project Report	10/28/2004	65A0030/0052
OCMDI Project Report	2/20/2004	65A0030/0040
Traffic Signal Integration (RAMS) Project Report	11/23/2004	65A0030/0055
Transit Mgt System (RAVL) Project Report	11/30/2004	65A0030/0053
TravelTIP Project Report	2/16/2004	65A0030/0036
5 Cross-Cutting Evaluation Reports		
System Performance Cross-Cutting Report	**11/30/2004**	**65A0030/0056**
Costs Cross-Cutting Report	11/30/2004	65A0030/0057
Institutional Issues Cross-Cutting Report	11/30/2004	65A0030/0058
Information Management Cross-Cutting Report	11/30/2004	65A0030/0059
Transportation System Impacts Cross-Cutting Report	11/30/2004	65A0030/0060
Final Summary Evaluation Report		
Showcase Program Evaluation Summary Report	11/30/2004	65A0030/0061

The System Performance evaluations of the individual Showcase projects took a snapshot of each system at a point when each was "broken in" and in steady-state operation. The evaluations were based on quantitative and qualitative data gathered from user logs, interviews, and project documentation, depending on the particular objective and measure being evaluated.

The System Performance Cross-cutting Evaluation aggregates and summarizes information from those individual Showcase projects that have been completed to-date. More specifically, this evaluation aggregates and summarizes information from across the individual Showcase projects with specific regards to Evaluation Goal 1, which includes the following supporting evaluation objectives:

Objective 1.1 – Document the project's system development process, including configuration management.

Objective 1.2 – Assess overall system reliability, availability, compatibility and scalability.

> **(Note: Although Interoperability and Ease-of-Use were also included under Objective 1.2 in the Showcase Program's 1998 Evaluation Strategy, the Priority Corridor's Evaluation Subcommittee agreed that these topics deal more with user acceptance, which is already covered under the Transportation & Traveler Information Management evaluation.)**

Objective 1.3 – Assess how Showcase Program integration affected deployment of individual Showcase Program projects and their system performance.

These objectives have been refined to the set of evaluation measures and data elements found in Exhibit 1.

Exhibit 1 – Basis of the System Performance Evaluation

Objective 1.1 Document the Showcase Program system development process, including configuration management

Measures	Supporting Data
1.1.1 Document the system development process, including configuration management	• Project deliverables • Observations

Objective 1.2 Assess the overall system reliability, availability, compatibility and scalability

Measures	Supporting Data
1.2.1 Mean Time Between Failures (MTBF)	• Recorded system failures • Total actual operating time
1.2.2 System availability equation	• Total scheduled operating time • Actual operating time
1.2.3 Assessment of level of compatibility in physical and operational environment by transportation agency technical staff	• Observations of incompatibilities or anomalies caused by system interference
1.2.4 Estimate of scalability	• System design

Objective 1.3 Assess how Showcase Program integration affected deployment of individual Showcase Program projects and their system performance

Measures	Supporting Data
1.3.1 Document how integration affected deployment of individual projects and their system performance	• Changes in project schedules, designs, etc.

Objective 1.1 documents each project's system development process(es), including configuration management. It describes the planning and systems engineering approaches that were followed and illustrates the system development through a "Project Evolution Timeline." This cross-cutting evaluation will examine the similarities and differences in the projects' processes and their times to deployment or completion.

Objective 1.2 documents total system downtime, up time, Mean-Time-Between-Failure (MTBF) and Availability, as well as categorizes the types of anomalies and failures that occur. Downtime is defined as the total accumulated time that the system is fully or partially out of operation due specifically to a failure (planned downtimes for routine or preventative maintenance are not counted). "Up time" is the total accumulated time that the system is operational.

MTBF is a measure of how long a system operates, on average, before it fails. MTBF will be calculated from the log data by dividing the total cumulative time of system operation by the number of recorded failures.

MTBF = Total Actual Operating Time (units of time) / Number of System Failures (scalar)

Availability is defined by the IEEE as the degree to which a system or component is operational and accessible when required for use. It is computed as the ratio of a system's actual "in service" operating time to its scheduled or expected operating time. Note that "in service" operation excludes time spent testing the system "off-line."

Availability = Total Actual Operating Time / Total Expected Operating Time

Compatibility is the ability of two or more systems or components to perform their required functions while sharing the same hardware or software environment. Agency personnel will be interviewed to determine whether they have witnessed any system anomalies that might be attributed to interference or system incompatibilities.

Scalability is the degree to which a system can be modified (upgraded) to accommodate additional users or functionality. The system developer will be interviewed and asked to provide evidence of the scalability of the system.

This cross-cutting evaluation will examine the similarities and differences in these performance measures in order to help uncover trends and establish performance expectations for these systems.

Objective 1.3 documents the impact of Corridor-wide integration on individual Showcase project deployments. Impacts might include, but are not necessarily limited to:

- Schedule changes
- Design changes
- Budget changes

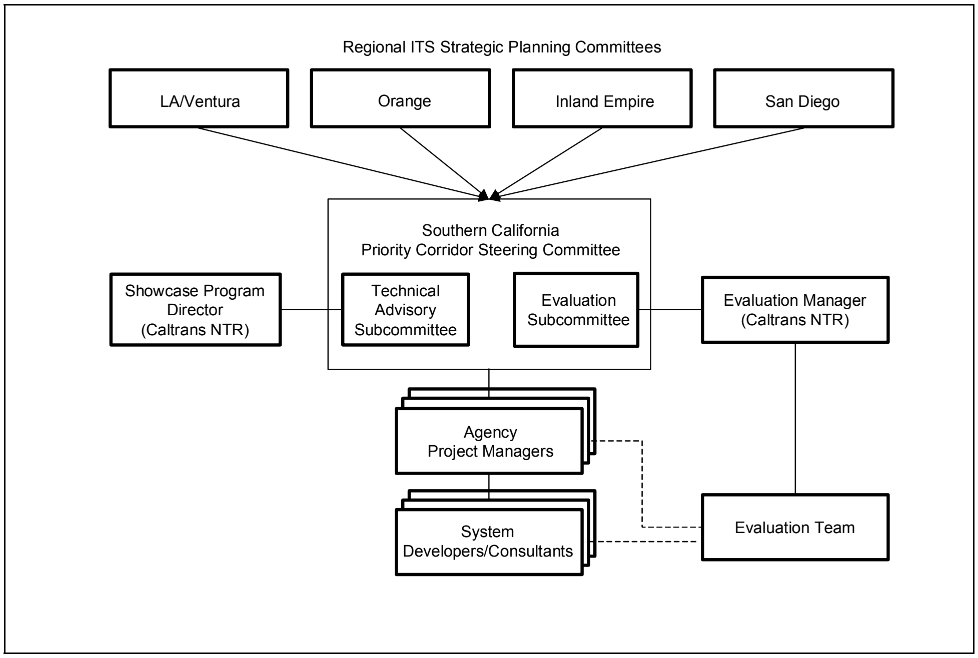
1.2 Evaluation Design and Approach

The Showcase Program's Evaluation Design is based on a set of evaluation Goals and supporting Objectives and Measures that were developed by the Evaluation Team in partnership with federal, state and local stakeholders (shown in Exhibit 2), and documented in the "Showcase Program Evaluation Approach" in 1998. Each individual Showcase project is evaluated based on an applicable subset of these goals, objectives, and measures in order to help ensure that summary evaluation results can be aggregated from across the multiple Showcase project evaluations. The Showcase Program's five evaluation Goals include:

- Evaluate System Performance
- Evaluate Costs
- Evaluate Institutional Issues and Impact
- Evaluate the Use and Management of Transportation/Traveler Information (i.e., Evaluate User Acceptance)
- Evaluate Transportation System Impacts.

The evaluation is responsive to the needs and suggestions of the Priority Corridor Steering Committee and Evaluation Subcommittee. As shown in Exhibit 2, both groups are comprised of stakeholders from the federal, state, and local levels.

Exhibit 2 – Management Structure and Organization of the Showcase Program



The Steering Committee's member agencies reflect wide representation from the Southern California Priority Corridor in terms of federal and state highway agencies, public safety, cities and counties, transit, air quality and regional planning entities, including:

- California Highway Patrol (CHP)
- Caltrans, Division of Traffic Operations (headquarters)*
- Caltrans, District 7*
- Caltrans, District 8*
- Caltrans, District 11*
- Caltrans, District 12
- City of Irvine*
- City of Los Angeles Department of Transportation (LADOT)
- City of San Diego
- Federal Highway Administration (FHWA)*
- Federal Transit Administration (FTA)
- Los Angeles County Metropolitan Transportation Authority (MTA)
- Orange County Transportation Authority (OCTA)
- Riverside County Transportation Commission (RCTC)
- San Bernardino Association of Governments (SANBAG)
- San Diego Association of Governments (SANDAG)
- South Coast Air Quality Management District (SCAQMD)
- SCAG

* Indicates an Evaluation Subcommittee member

The Evaluation Subcommittee consists of Caltrans' Evaluation Contract Manager and representatives from FHWA, Caltrans headquarters, and each of the four regions of the Priority Corridor. The Evaluation Subcommittee reviews evaluation issues and products. All draft evaluation documents are submitted to the Evaluation Subcommittee for review and comment before being finalized.

1.3 Privacy Considerations

Some of the information acquired in the interview and discussion process could be considered sensitive and has been characterized in this report without attribution. The Evaluation Team has taken precautions to safeguard responses and maintain their confidentiality. Wherever possible, interview responses have been aggregated during analysis such that individual responses have become part of a larger aggregate response. The names of individuals and directly attributable quotes have not been used in this document unless the person has reviewed and expressly consented to its use.

1.4 Constraints & Assumptions

Not all of the Showcase Program projects developed a system. Those that did develop a system – and that were used to prepare this report – include:

- CW Rideshare
- Fontana-Ontario ATMIS
- IMAJINE
- IMTMS/C
- InterCAD
- Kernel
- LA/Ventura ATIS
- Mission Valley ATMIS
- Mode Shift
- OCMDI
- RAMS
- RAVL
- TravelTIP

Based on their respective scopes or schedules, the following four projects were not used to prepare this report:

- CWATMS
- CWATIS
- CWCVO
- CWSPP

1.5 Background

1.5.1 The Southern California Priority Corridor

In 1993, the U.S. Department of Transportation designated Southern California as one of four Priority Corridors in which Intelligent Transportation Systems (ITS) could have particular benefit. The Southern California Priority Corridor, illustrated in Exhibit 3, is one of the most populated, traveled, and visited regions in the country. Roughly two-thirds of the state's population – about 20 million people – resides in or around the Southern California Priority Corridor. It suffers from extreme traffic congestion, limited room for expanding transportation facilities, and above-average air pollution levels.

The Southern California Priority Corridor consists of four distinct regions that correspond with the four Southern California Caltrans districts:

- Los Angeles/Ventura (Caltrans District 7)
- Orange County (Caltrans District 12)
- San Diego (Caltrans District 11)
- Inland Empire (Caltrans District 8)

Exhibit 3 – The Southern California Priority Corridor and Vicinity

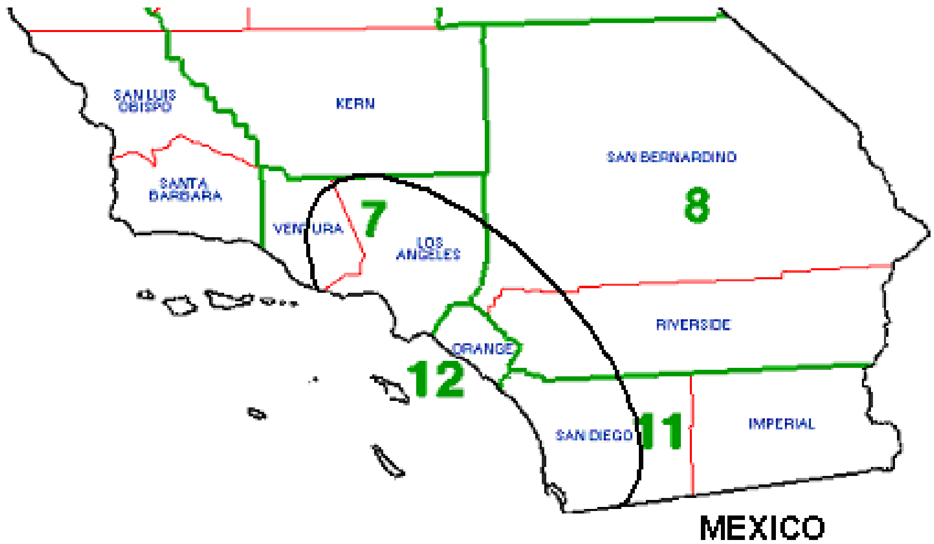


Exhibit 4 – Population and Number of Registered Vehicles by County

County	Population[i] (as of 1/1/2003)	Registered Vehicles[ii]* (as of 12/31/2002)	Caltrans District
Los Angeles	10 million	6.7 million	7
Orange	3 million	2.2 million	12
San Diego	3 million	2.3 million	11
San Bernardino	1.8 million	1.3 million	8
Riverside	1.7 million	1.2 million	8
Ventura	0.8 million	0.7 million	7
Imperial	0.15 million	0.1 million	11
Total	**20.5 million**	**14.5 million**	

*Includes autos, trucks, and motorcycles. Trailers not included.

1.5.2 The Southern California Priority Corridor's ITS Showcase Program

The ITS Showcase Program is one of several programs that have been implemented in Southern California's Priority Corridor to help aid mobility and mitigate traffic congestion and its associated environmental impacts.

The Southern California ITS Showcase Program consists of 17 individual ITS projects that collectively form a corridor-wide intermodal transportation management and information network between Los Angeles, Orange County, San Diego, and the Inland Empire. Eleven of the projects are regional in nature, while the remaining six are corridor-wide in scope. The 17 Showcase projects are listed by region in Exhibit 5. Eight of the projects were fast-tracked and designated "Early Start" projects because of their importance as base infrastructure and potential to act as role models for the rest of the Showcase Program.

Exhibit 5 – The 17 Showcase Projects and their Status as of September 2004

Project	RFP Issued	Contractor Selected	Contract Executed	Project Underway	Project Complete
Corridor-wide					
Scoping & High Level Design (Kernel)*	✓	✓	✓	✓	✓
Strategic Planning/Systems Integration	✓	✓	✓	✓	✓
CVO🗎					
ATIS	✓	✓	✓	✓	✓
ATMS🗎					
Rideshare	✓	✓	✓	✓	✓
Los Angeles Region					
IMAJINE*	✓	✓	✓	✓	✓
Mode Shift*	✓	✓	✓	✓	✓
LA ATIS	✓	✓	✓	✓	✓
Inland Empire Region					
Fontana-Ontario ATMIS	✓	✓	✓	✓	✓
Orange County Region					
TravelTIP*	✓	✓	✓	✓	✓
OCMDI	✓	✓	✓	✓	✓
San Diego Region					
InterCAD*	✓	✓	✓	✓	✓
Mission Valley ATMIS*	✓	✓	✓	✓	✓
IMTMS/C (ATMSi)*	✓	✓	✓	✓	
Traffic Signal Integration (RAMS)	✓	✓	✓	✓	
Transit Management System*	✓	✓	✓	✓	

* Indicates an "Early Start" project.
🗎 CWCVO and CWATMS do not yet have approved workplans.

Exhibit 6 – Projects Contributing to Cross-Cutting Evaluation

ITS Project	Cross-Cutting Evaluation/Objectives																		
	System Performance			Cost		Institutional Impacts & Issues					Transportation & Traveler Info Mgt.			Transportation System Impacts					
	System Development Process	System Reliability	Showcase Program Integration	Estimate Costs Asociated w/Program's Philosophy	Estimate O&M Costs	Impact on O&M Procedures & Policies	Impact on Staffing/Skill Levels and Training	Impacts of Emerging Standards	Participation by Private Sector in Mgmt of Trans and Traveler Info	Impact on Local Planning Process, Policy Dev, & Mainstreaming of ITS Projects	Utilization of Regional/Interregional Information Integration	Utilization of Regional/Interregional Information & Traveler Information	Extent of Traveler Information Disseminated and Used by Travelers	Mode Shift & Intermodal Impacts	Safety Related Impacts	Impact on Traffic Congestion	Environmental Impacts	Impact on Transit Operations	Impact on Commercial Vehicle Operations
	1.1	1.2	1.3	2.1	2.2	3.1	3.2	3.3	3.4	3.5	4.1	4.2	4.3	5.1	5.2	5.3	5.4	5.5	5.6
CWATIS				X															
CWATMS				X															
CWCVO				X															
CW Rideshare	X			X							X	X							
CWSPP				X		X				X									
Fontana-Ontario	X	X	X	X	X	X	X		X		X	X	X						
IMAJINE	X		X	X	X		X	X			X	X							
IMTMC				X							X	X							
InterCAD	X			X	X							X							
Kernel	X		X	X	X			X			X								
LA/Ventura ATIS	X			X	X			X			X		X						
Mission Valley ATMIS	X			X	X	X			X	X	X	X	X						
Mode Shift	X			X	X								X						
OCMDI	X	X		X	X				X	X			X						
RAMS				X															
RAVL				X															
TravelTIP	X		X	X	X	X	X	X			X	X	X	X	X			X	

2 Evaluation Findings

This chapter provides the Showcase Program's aggregated findings regarding system development and performance broken out by evaluation objective.

Objective 1.1 – System Development

Project Implementation Schedules

Most of the Showcase contracts originally specified periods of performance (PoPs) of about 18-24 months; however, few projects were able to meet these schedules. It is not clear how the original PoPs were determined or whether these original schedules were at all realistic. As shown in Exhibit 6, experience from the Showcase Program suggests that, on average, 48 months is a more realistic PoP.

ITS projects require about 48 months to complete due mainly to process, planning, and consensus building. In virtually every example from the Showcase Program, the project needed 18 or more months just to develop and document system requirements and a high-level design. Since many of the Showcase projects were meant to integrate systems from several local agencies, the system requirements phase required substantial coordination and consensus building among each project's various stakeholders. The coordination process – often difficult even under the best conditions – was further complicated by the fact that many of the participating agency staff were only committed part-time to the Showcase effort, and had to balance the time demands of the Showcase Program against their regular routine responsibilities. This often resulted in the review cycles of draft documents lasting anywhere from 1-12 months. Although stricter deadlines could have been placed on document reviews, the general view was that it was more important that all comments be heard, rather than exclude anyone's input just to push ahead.

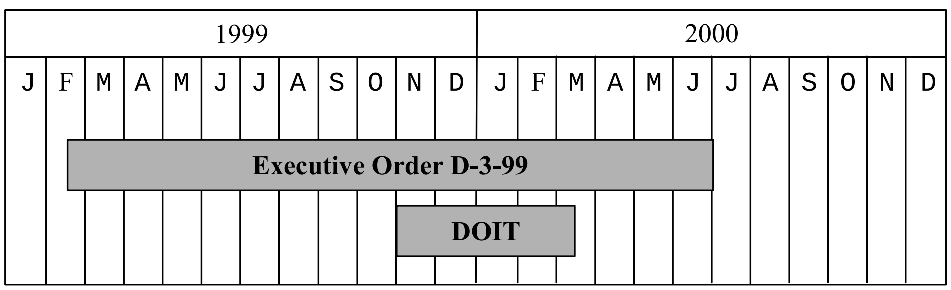
Exhibit 7 – Comparison of Originally Planned and Actual Project PoPs

Project	Original PoP (months)	Actual PoP (months)
CW Rideshare	7	22
Fontana-Ontario ATMIS	na	49
IMAJINE	18	52
IMTMS/C	na	TBD
InterCAD	18	72
Kernel	na	77
LA/Ventura ATIS	18	42
Mission Valley ATMIS	na	51
Mode Shift	20	47
OCMDI	13	36
RAMS	na	TBD
RAVL	18	30+
TravelTIP	13	60

Another contributor to the perceived delay was fear over the “Y2K bug,” or the inability of software systems to handle the date rollover to 1/1/00. On 17 February 1999, and in anticipation of possible “Y2K” problems, California Governor Gray Davis took a preemptive step and signed Executive Order D-3-99. The order mandated that all Departments within the State of California defer any new non-Y2K information technology (IT) projects not required by law. D-3-99 prevented the Showcase Kernels from being installed at the Caltrans TMCs until after July 2000.

On 30 July 1999, the California Department of Information Technology (DOIT) announced its own moratorium on the purchase and/or installation of any computer systems (hardware or software) not related to Y2K risk mitigation. The moratorium applied to all departments within the State of California for the period of 1 November 1999 through 10 March 2000. This moratorium was in addition to the one issued in February by Governor Davis, which restricted IT purchases through July 2000.

Exhibit 8 – The Effective Dates of the two ‘Y2K’ Moratoria

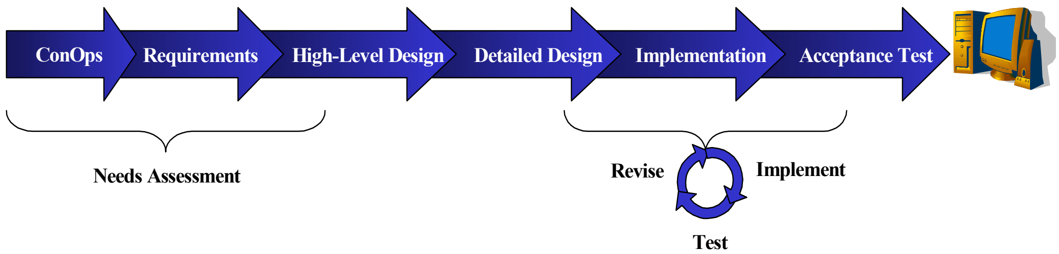


System Development Process

Effective since April 2001, several years after the start of the Showcase Program, the Federal Highway Administration and Federal Transit Administration have required the use of a systems engineering approach in the development of any federally-funded ITS projects. Lessons learned during the Showcase Program provide empirical evidence as to why using the National ITS Architecture and a system engineering approach are so important.

In general, the system engineering process provides a logical progression from identifying needs to building a system that satisfies those needs. This progression is shown in Exhibit 9.

Exhibit 9 – The Basic System Engineering Process



Concept of Operations (ConOps) – This document helps establish a single, shared vision of the end product by describing how the prospective system will be used, by whom, and when. This document can quickly point out the desired functionality and whether there may be any institutional issues such as liability concerns over the shared use of field devices. The identification and assessment of needs begins at a high level with the ConOps, but delves deeper during the gathering of Requirements.

Requirements – When sufficient detail has gone into the ConOps and project stakeholders have agreed on a vision of the end product, the system developer can begin describing the product as a list of specific system requirements. Such a set of Requirements might conceivably dictate not only that the final system shall exchange data between points **A** and **B**, but also that it shall do so over a particular connection medium, with a specified level of security, and using a particular method or set of protocols.

High-Level Design – Once the Requirements are known, the system developer can begin designing one or more potential solutions. These are initially presented at a high level to enable a technical and/or cost analysis of the alternatives. Once a solution is chosen, the system developer can begin refining the design.

Detailed Design – As the name implies, this phase of development refines the high-level solution in preparation for actual implementation and installation. This phase might include the development of several deliverables, including a Detailed Software Design, a Detailed Hardware Design, a Communications Plan or design, and an Installation Plan.

Implementation – The Implementation phase represents the purchase, development, and installation of the system hardware and software. In reality, this phase is most often part of an iterative cycle in which technical challenges or lessons learned during implementation and testing result in a modification of the detailed design. Although some iterative development is virtually unavoidable, a project should avoid falling into an endless cycle of "build-and-fix." This sometimes happens when the solution to one problem inadvertently breaks another part of the system and causes a new problem.

Acceptance Testing – Although various levels of testing are conducted throughout implementation, an Acceptance Test of the installed final system is necessary to prove that all system requirements have been satisfied and that the system developer has met his or her contractual obligations.

The Showcase projects generally followed this approach with most project tasks corresponding with the steps above; however, there were a few exceptions, which are discussed below.

Concept of Operations (ConOps)

While a few did, the majority of the Showcase projects did not include a task to develop a ConOps. As a result, a few encountered institutional issues late in their development that limited their success. Some of these issues include:

- Restrictions on integrating with, or accessing, secure networks maintained by law enforcement agencies,

- Lack of funding, personnel, or commitment to operate and maintain the system as originally envisioned by some stakeholders.

A ConOps can help identify where a system will physically reside, what resources might be necessary to operate and maintain it, and whether any interagency agreements or MOUs are necessary. Although a ConOps will not guarantee project success, it can help reduce the risk of failure. Had a ConOps been prepared for these projects, the agency partners might have identified the issues early enough either to resolve them or to redirect the project to make better use of its limited resources.

Requirements Gathering

The Showcase projects used a combination of monthly meetings and special workshops to bring together stakeholders for discussions on system requirements and technology issues. So as not to discourage any ideas, potential system requirements were often gathered at the workshops in a brainstorming fashion under the assumption that money was no object. Once the complete “wish list” of requirements was collected, the project team then deliberated on which ones were feasible to implement given the state of technology and the project’s available budget. Some projects prepared an Implementation Phasing Plan (IPP) so that none of the stakeholders’ needs or ideas would be discarded and go undocumented. An IPP captures the entire “wish list” of requirements, but separates those that will be implemented by the current project from those that must be deferred and implemented later.

The regular monthly project meetings were an effective way to track project progress, but highly technical discussions generally had to be deferred to special meetings or workshops. Overarching, Corridor-wide policy and program management issues were handled by the Priority Corridor Steering Committee, which met once per month. The Steering Committee consists of wide representation from across the Southern California Priority Corridor and includes federal and state highway agencies, public safety, cities and counties, transit, air quality and regional planning entities. This wide representation makes it a unique and valuable working group within Southern California. As the Showcase Program comes to an end, the Steering Committee members plan to continue to meet as the Southern California ITS Forum.

Design & Implementation

Several lessons were learned during the design and implementation phases of the Showcase projects:

- System designs must be properly documented,

- Intellectual Property Rights (IPR) must be addressed early.

The Showcase Program includes 17 projects with at least five major contractors and several smaller subcontracting firms. Collectively, the Showcase projects create a “system of systems” that includes several regional ATMS and ATIS integrated locally by regional networks and integrated Corridor-wide by the Kernels and the interregional network. With so many layers of integration – and several teams simultaneously at work – documenting and sharing system designs and interface information became a critical issue. In fact, at least one Showcase project (and one other non-Showcase project) chose not to integrate to the Kernel network because they felt that the technical documentation was not sufficient.

Large integration programs such as Showcase should not underestimate the value of budgeting for technical writers to prepare and maintain accurate and thorough documentation of system designs and interfaces throughout the project lifecycle. When specifically describing an object-oriented software system, such documentation should include, at a minimum, class diagrams, sequence diagrams, and textual descriptions of the classes that explain how their attributes and methods are to be used. Here is a list of industry standards that agencies might consider for preparing requirements specifications and design documentation:

- ISO/IEC 12207
- IEEE 1233
- IEEE 1471
- U.S. Department of Defense DI-IPSC-81433
- BSI BS-5515
- BSI BS-7738
- NASA DID-P400 & P410

Since design, implementation, and testing is often an iterative process, it is ideal to update the system’s technical documentation continually through the end of the project.

Concerns over the accuracy and completeness of the technical documentation, a desire to share and reuse software source code between projects, and an attempt to institute

Corridor-wide configuration management also raised several issues with Intellectual Property Rights (IPR).

For the reasons above, several projects wanted access to the custom software source code being developed by other contractors on other Showcase projects. In the first case, the source code was requested in order to validate and augment the technical documentation that was at least perceived to be untrustworthy. In the second case, it seemed more practical to reuse source code that had already been developed rather than spend additional time and money "reinventing the wheel." In the third case, Caltrans wished to create a software source code clearinghouse and institute Corridor-wide configuration management in preparation for long-term support of the Showcase systems. Although the software developed by the Showcase projects was funded entirely by tax dollars – with no private-sector cash or in-kind investments – legal precedents show that the private firms who develop the new software still retain certain IPRs.

An agency may use or modify the software – and perhaps even share it with other public agencies – but it may not share or disclose the source code to any private-sector entities. This is because the source code might contain unique, proprietary innovations or "trade secrets," which – if revealed – could compromise a developer's market advantage.

However, the rights and responsibilities of the public and private partners in an ITS project are bound by the terms of the project contract(s). Agencies must ensure that their ITS contracts contain specific language that addresses IPR and the ownership of – and restrictions regarding – custom-written software source code.

Testing

The Showcase contractors followed standard industry practices of conducting unit tests or "bench tests" of individual system components prior to installation, and then closing out the project with a final Acceptance Test of the fully installed and integrated system. Detailed test procedures were prepared to ensure that all system requirements and functionality were appropriately tested, that the expected results could be identified and observed, and that any unexpected results or anomalies could be recorded and retested.

Operations & Maintenance (O&M)

The Showcase projects typically included an operations and maintenance (O&M) period of 6-18 months to help fund the new systems while they proved their worth and could be included as a regular part of the agencies' annual budgets.

Contracting ITS Projects

There are two other important aspects to structuring an ITS project. Although the tasks and content of the project will follow the systems engineering approach, ITS practitioners must also consider two other questions:

- Should the project be structured as a single contract that designs and builds the system, or should there be multiple contracts or a Task Order Agreement?

- How should the contractor(s) be paid? On a cost-plus-fee basis, a time-and-materials basis, or according to a fixed price per deliverable?

With the exception of three projects, each Showcase project used its own single contract to scope, design, and build its system. Furthermore, all but one of these contracts specified a fixed price per deliverable. Using a single fixed-price contract both to design and build a system is not necessarily bad, but there can be advantages to using other methods.

Most of the Showcase projects originally specified a total period of performance of 18 months, but ended up taking closer to 48 months due to the upfront coordination and consensus building between the stakeholders. Although software development and installation of the system was often accomplished in an 18-month period, the time required by the stakeholders to plan, design, document, and reach consensus on the system often amounted to nearly three years. At the quick pace of technology advancements, this can be an eternity for software and hardware-related projects. In fact, by the time many of the Showcase projects went operational, their hardware – which had been procured early in the project – had already become obsolete.

ITS practitioners might consider using separate design and build contracts or task orders so that planning can take place independent of system development. A separate design phase would provide time for agency stakeholders to reach consensus on needs and system requirements, develop a detailed ConOps, and put in place the necessary institutional agreements to help ensure the system's successful and continued operation once built. It would also help agencies mitigate any risks associated with committing to build a system before the needs or institutional issues are fully understood. Since the level of effort and duration of this phase is unpredictable, it should be contracted as cost-plus-fee or time-and-materials.

Once the needs and requirements are well understood and documented, detailed design and implementation should be straightforward. This phase of the project can be contracted as fixed price.

Using a Task Order Agreement may also provide potential benefits. For example, this approach provides maximum flexibility through the recurring opportunity to reevaluate investment decisions and technology choices after each task order.

Many of the Showcase projects are the first of their kind for Southern California. As the local agencies learn more about what their constituents want and need, and the private sector develops new technologies and solutions, ITS in Southern California will continue to improve. None of the systems developed by Showcase should be considered final products, but rather milestones in an ongoing evolution.

Objective 1.2 – Reliability, Availability, Compatibility and Scalability

The Showcase Evaluation studied the availability, reliability, scalability and compatibility of the Showcase Program's delivered systems. Since a new system often experiences a "shakedown" period during which the developer corrects problems and tunes the system for optimal performance, the system performance evaluation studies the optimized or "steady-state" operation of the system.

Reliability

There has been no evidence of any system failures.

Objective 1.2 documents total system downtime, up time, Mean-Time-Between-Failure (MTBF) and Availability, as well as categorizes the types of anomalies and failures that occur. Downtime is defined as the total accumulated time that the system is fully or partially out of operation due specifically to a failure (planned downtimes for routine or preventative maintenance are not counted). "Up time" is the total accumulated time that the system is operational.

MTBF is a measure of how long a system operates, on average, before it fails. MTBF is calculated by dividing the total cumulative time of system operation by the number of recorded failures.

MTBF = Total Actual Operating Time (units of time) / Number of System Failures (scalar)

To the credit of the Showcase Program's contractors, the systems that have been developed have not encountered any hardware or software-related failures. However, many of the systems are currently being underutilized due to:

- A lack of public outreach resulting in low public usage,
- No resources yet identified for long-term O&M,
- Insufficient training or encouragement for agency operators to use the new systems.

Two systems that are in daily use include the Fontana-Ontario ATMIS and the traveler information services provided by the Traveler Advisory News Network (TANN).

One of the interesting design features of the Fontana TMC is that it utilizes Windows©-based workstations. Until the release of Windows 2000, it has been traditional for similar projects to rely on UNIX-based workstations because of their relatively superior reliability over older version of Windows©. However, gradual improvements in the Windows© operating system has made the reliability of PC workstations comparable to that of their UNIX counterparts, but at much lower cost.

In roughly one year of operation, there have been only two situations that have caused at least a partial failure of the workstations in the Fontana TMC. Both cases were caused by computer viruses. In the first case, an employee accidentally brought in an infected disk. In the second case, the City server was infected and a computer "worm" made its way through the network to the TMC. Virus protection software has since been installed to help mitigate similar future incidents.

Availability

Of Showcase's system deployments, all but three are currently operational and available in some capacity.

Availability is defined by the IEEE as the degree to which a system or component is operational and accessible when required for use. It is computed as the ratio of a system's actual "in service" operating time to its scheduled or expected operating time. Note that "in service" operation excludes time spent testing the system "off-line."

Availability = Total Actual Operating Time / Total Expected Operating Time

Although mostly underutilized for the reasons stated in the last section, those systems that are still operational show no signs of failures and, therefore, have 100% availability. Three of the systems, however, are currently inoperative and have 0% availability.

Compatibility

There are no indications of any system incompatibilities.

Compatibility is the ability of two or more systems or components to perform their required functions while sharing the same hardware or software environment. Throughout the 17 Showcase projects, there have not been any system failures or anomalies that would indicate an incompatibility with the existing software/hardware environment.

Scalability

The Showcase software and system architecture are designed to allow expansion of the systems to accommodate the addition of users without limitation.

Scalability describes the extent to which system usage can grow without sacrificing system performance or requiring architectural or technology changes. Most of the Showcase systems use a mixed peer-to-peer and client-server architecture, which avoids putting too much load on a single, central server. This architecture allows unbounded expansion of the system. Most of the systems' constraints lie with the communications architecture and network component capacity. Currently, much of the communications are via agency-owned fiber-optic cable or through commercial leased service. However, in either case, additional bandwidth can be obtained as needed as new centers and workstations are added to the network and brought online.

Objective 1.3 – Impact of Showcase Integration on Project Deployment and System Performance

The Showcase Program was a highly ambitious effort to plan, design, build and seamlessly integrate several regional ATIS and ATMS in Los Angeles County, Orange County, the Inland Empire, and San Diego. Several complementary Corridor-wide projects were also conducted as part of the Showcase Program to develop an interregional infrastructure and help bring the regional pieces together as a single "system of systems." This required a tremendous amount of coordination and consensus building between the projects to arrive at a common architecture and a set of standard system interfaces. Much of this effort was conducted and documented by the Scoping & Design contract, which also developed the Showcase Kernels.

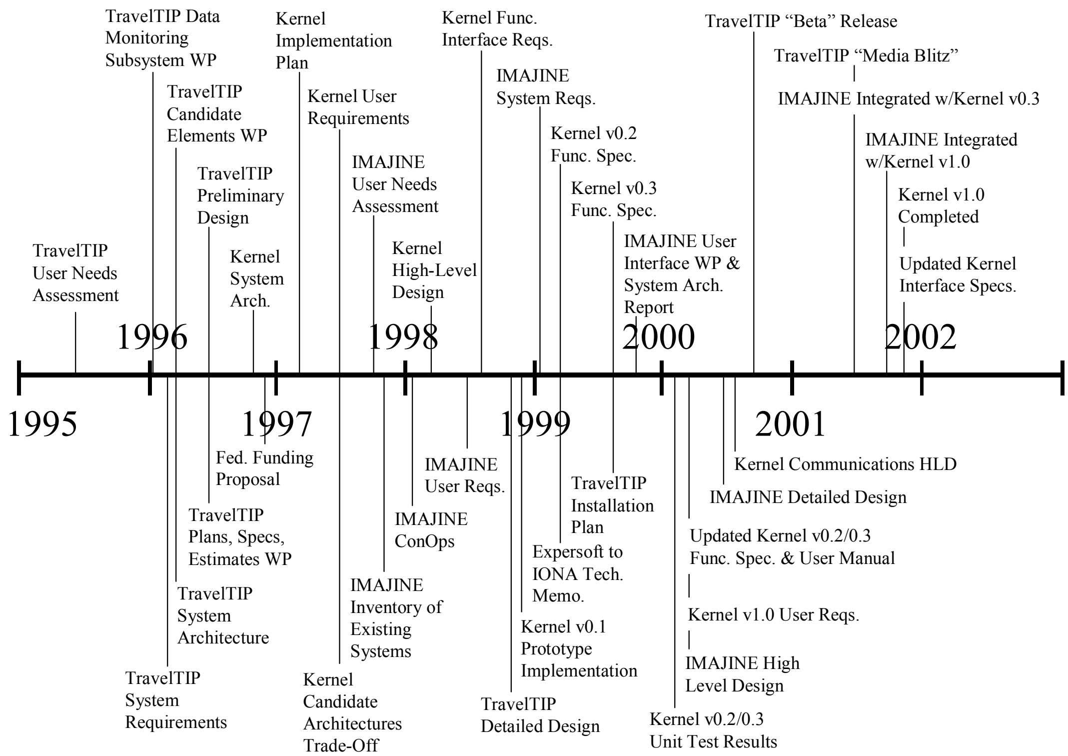
The four Kernel servers – one located at each of Caltrans' four Southern California TMCs – provide "common services" that enable regional centers to log on/off of the Showcase Network, view a "white pages" and "yellow pages" of data that is available on the network, as well as publish and subscribe to available traffic "event" information. In addition, the Kernels monitor the communications system and alert regional centers to system failures. Although the Kernels make these "common services" available, it is up to the developers of the regional systems to design and implement their software to make use of these services.

Depending on the type of data being exchanged, the regional systems are designed to communicate with each other either peer-to-peer or through the Kernels using Showcase's standardized objects and commands, which are contained and documented in CORBA-based Interface Definition Language (IDL). Arriving at this Corridor-wide standard for Showcase's system interfaces is one of the Program's greatest achievements, and it required years of coordination between the projects.

This collaborative, give-and-take design process between the regional projects and the Scoping & Design (Kernel) project is yet another contributor to some of the perceived delays in deploying the Showcase projects. Although this collaboration between the projects during their design and implementation phases may seem to have slowed their development, it undoubtedly was necessary to achieve a more robust and integrated "system of systems."

Exhibit 10 provides only a glimpse of the number of parallel efforts that were taking place throughout much of the Showcase Program. The timeline shows only three projects, although as many as 15 projects were actually underway at various points during this period.

Exhibit 10 – Joint Timeline of the IMAJINE, TravelTIP and Kernel Early Start Projects



Conclusions

The probability of success of an ITS project is often determined before its contract is signed. When contracting ITS projects, agencies should consider several issues:

- Have Intellectual Property Rights (IPR) regarding the source code of any custom-developed software been adequately addressed in the Request for Proposals (RFP) and the contract template?

- If other systems might eventually integrate with this one, will its interfaces be properly documented "as built?"

- Are the expectations for the project realistic?

- Is the project compliant with the National ITS Architecture?

In general, legal precedents restrict public agencies from sharing custom-developed software source code with private third-parties, even if the software development was entirely funded by the public sector. This is because the source code may contain proprietary innovations or "trade secrets" of the developer, which may not be disclosed to the marketplace. However, agencies that have their own Information Technology staff may often negotiate the right to view and modify the code "in house" or to share the source code with other public agencies within the same region or state. Such sharing can benefit regional standardization and integration.

Projects – particularly those that develop infrastructure – should not underestimate the importance of completely and accurately documenting system designs and interfaces. Many projects finalize their design documents at the end of the Design task, but before the implementation is complete. However, design changes often continue to take place as the developer encounters and overcomes the inevitable and unforeseen technical challenges that arise. To ensure that all of these changes are recorded, projects should budget for ongoing revision of design documentation until the end of the project, resulting in "as built" documentation.

Most of the Showcase projects required more than 48 months to complete even though their original schedules were for 18-24 months. As opposed to calling the projects "late," it seems more realistic that the level of effort was underestimated and that the original schedules were simply too aggressive. The Showcase Program revealed that – due to the vast amounts of interagency coordination often required – the Requirements and High-Level Design phases of an integration project can take 18-36 months alone, only to be followed by another 18-24 months of detailed design, implementation, installation, and testing. In the near term, ITS projects throughout the country should be expected to continue this pattern, though successive regional deployments and the development of regional architectures should eventually help streamline the process.

In early 2001 – roughly six years after the start of the Showcase Program – the Federal Highway Administration issued its "Rule on Intelligent Transportation Systems and Standards." The Rule contains two particularly important high-level requirements (and several supporting detailed requirements) regarding ITS planning and project implementation:

1. "A regional ITS architecture shall be developed to guide the development of ITS projects and programs and be consistent with ITS strategies and projects contained in applicable transportation plans."

2. "All ITS projects funded with Highway Trust Funds shall be based on a systems engineering analysis that is on a scale commensurate with the project scope."

One of the detailed supporting requirements in the Rule refers to developing an "operational concept" to define the roles and responsibilities of the participating agencies and to plan ahead for operations and maintenance. In practice, this can be achieved through the development of a Concept of Operations (ConOps) document.

A ConOps is a useful first step in a project because it can help the project stakeholders establish a common vision of the end product and a common understanding of how the system will be used. In addition, a ConOps can help uncover critical institutional issues early, such as:

1. Does the system require any shared use of field devices between agencies?

2. Does the system require access to any secure networks, as might belong to law enforcement/public safety?

3. Will the system require a human operator, or can it be automated? Are there any potential system operators available?

4. Are any interagency agreements or MOUs necessary to cover liability concerns or O&M costs?

The Showcase Program provides empirical evidence as to why a ConOps and the other requirements in FHWA's Rule are so important. The Showcase projects followed a logical systems engineering approach, but most of the projects began before the FHWA Rule was published and did not prepare a ConOps. As a result, several were impacted by institutional issues. Although the Showcase projects dealt with these issues eventually, identifying and resolving such issues early will help reduce risk and maximize a system's return on investment.

References

[i] California Statistical Abstract, Table B-4. California Department of Finance, Sacramento, CA. December 2003.

[ii] California Statistical Abstract, Table J-4. California Department of Finance, Sacramento, CA. December 2003.